Sept. 2, 1941. F. R. HENSEL ET AL 2,254,944

CYLINDER HEAD

Original Filed March 8, 1934 3 Sheets-Sheet 1

Fig. 1.

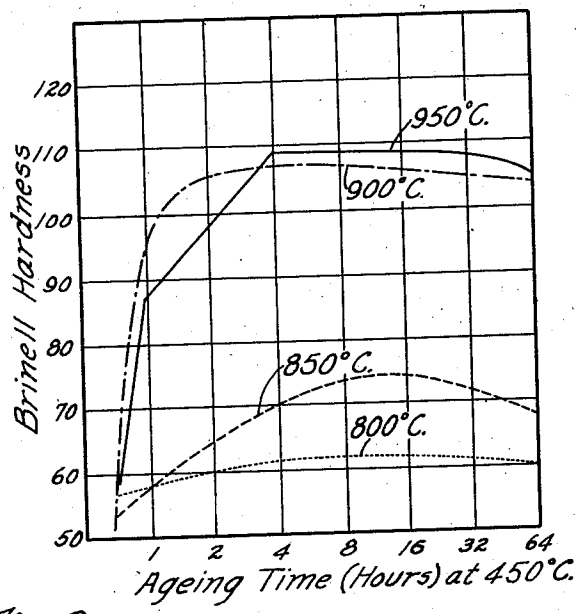

Fig. 2.

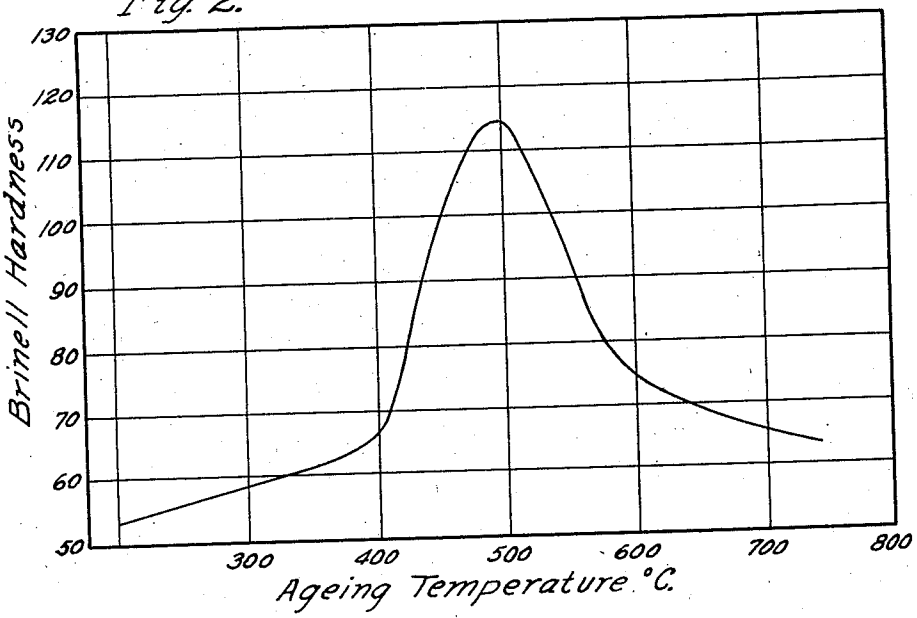

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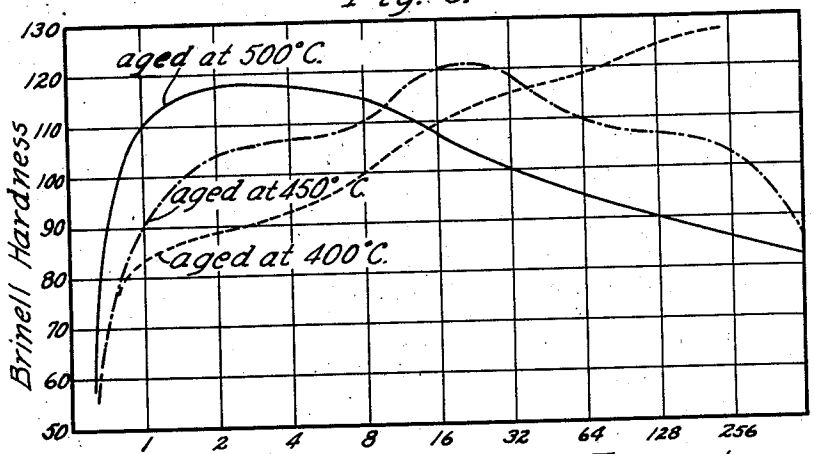
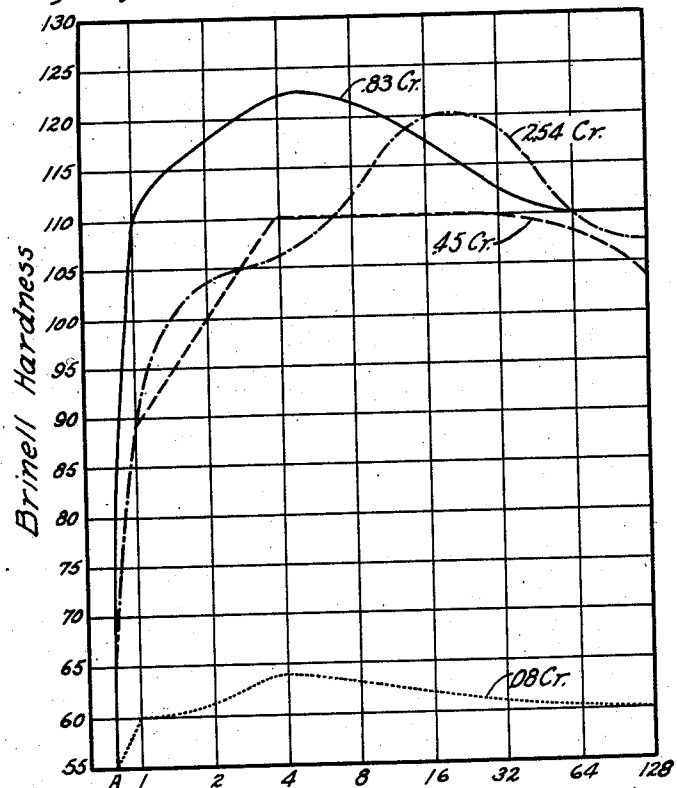
Fig. 3.



Ageing Time in Hours-Various Temperatures.

Fig. 4.



Ageing Time in Hours-Various Chromium Contents.

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Fig. 5.

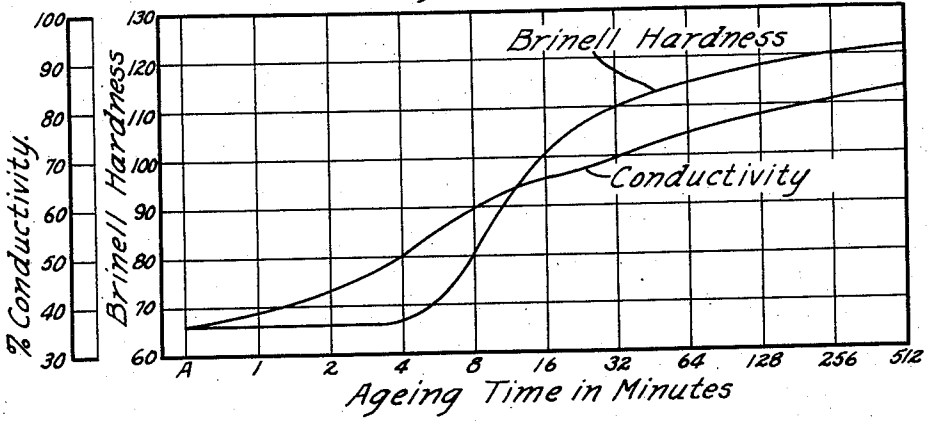


Fig. 6.

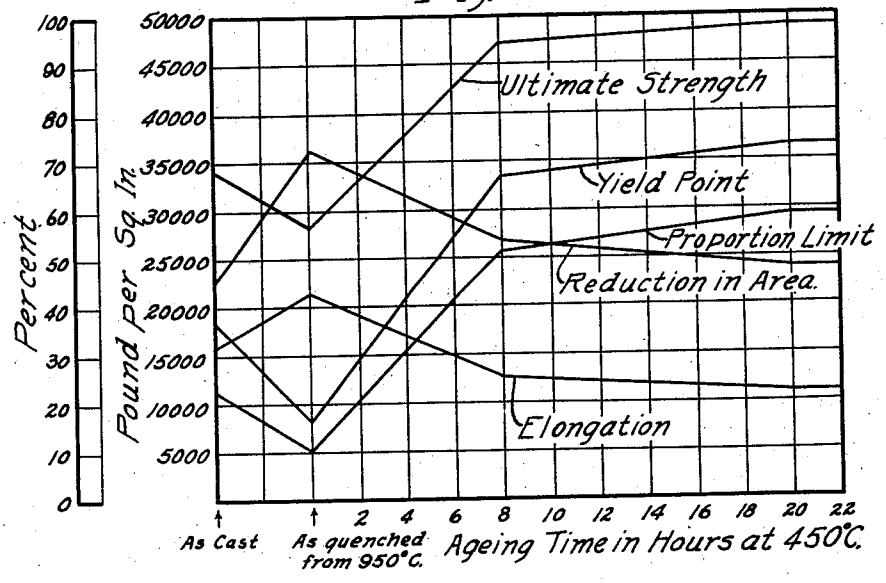


Fig. 7.

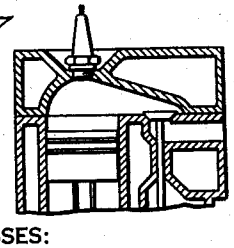
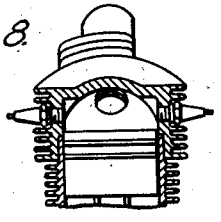


Fig. 8.



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UNITED STATES PATENT OFFICE

2,254,944

CYLINDER HEAD

Franz R. Hensel and Earl I. Larsen, Indianapolis, Ind., assignors to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Original application March 8, 1934, Serial No. 714,614. Divided and this application May 16, 1941, Serial No. 393,743

6 Claims. (Cl. 123—191)

This invention relates to articles formed from copper base alloys and, particularly, to cylinder heads for internal combustion engines formed of copper base alloys.

This invention is a division of our copending application, Serial No. 714,614, filed March 8, 1934, and directed to Copper alloys.

Certain metals have been alloyed with copper to produce an alloy having better mechanical properties, but, generally, such alloys have been inferior to copper as conductors of heat and electricity, and it has been difficult to duplicate the resulting characteristics. Further, it has been found that these alloys have an upper limit of stability for retaining their hardness and tensile strength of approximately 300° C. In addition, it has been difficult to produce the desired physical characteristics, such as by cold working, where the alloys are formed into articles that have been cast or forged to shape and which have a complicated design, such as, for example, cylinder heads for internal combustion engines.

It is an object of this invention to produce articles of manufacture formed to shape of a copper base alloy in which hardening elements are distributed throughout the resulting alloy in a finely divided state improving the conductivity and the mechanical properties of the alloy.

A more specific object of this invention is to provide a cylinder head for internal combustion engines formed of an alloy composed basically of copper and which is precipitation hardened to give the cylinder head high physical strength and conductivity.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a graph, the curves of which illustrate the effect of different quenching temperatures on the hardness of copper base alloys utilized in accordance with this invention;

Fig. 2 is a graph, the curve of which illustrates the effect of different ageing treatments on the hardness of alloys utilized in this invention;

Fig. 3 is a graph, the curves of which illustrate the effect of different ageing temperatures and time of treatment on alloys utilized in this invention;

Fig. 4 is a graph, the curves of which illustrate the effect of different chromium contents on the hardness values obtained;

Fig. 5 is a graph, the curves of which illustrate the simultaneous improvement obtained in both hardness and conductivity by precipitation hardening the alloys;

Fig. 6 is a graph, the curves of which illustrate the physical characteristics of the alloys utilized in accordance with this invention;

Fig. 7 is a vertical sectional view of a cylinder of an internal combustion engine with its head composed of the copper base alloy in accordance with this invention; and

Fig. 8 is a vertical sectional view of an air-cooled cylinder head formed of the copper base alloy in accordance with this invention.

In practicing this invention, it is preferred to employ an alloy which is basically copper and which is precipitation hardened to give it the necessary thermal and electrical conductivity and improve its mechanical properties. Alloys which have been found to be satisfactory are the copper base alloys containing up to 2.54% chromium, with or without additions of silicon, zirconium, cadmium, silver, cobalt, boron, uranium, and thorium.

The chromium content of the alloy is preferably maintained between .08% and 2.54%. The ternary alloys may contain in addition to the copper and chromium, from a small but effective amount up to 5% of zirconium or thorium, as covered in our Patent No. 2,025,662, issued December 24, 1935; from .1% to 5% of cadmium, as covered in our Patent No. 2,033,710, issued March 10, 1936; and from .01% to 5% or silver, as covered in our Patent No. 2,033,709, issued March 10, 1936, all of which are based on our copending application, Serial No. 714,614, filed Mar. 8, 1934, of which this application is a division.

In making the alloys, it is found that it is difficult to introduce the chromium into molten copper to form a solution, for the chromium dissolves slowly, and the amount finally dissolved is small. Free chromium differs in density from copper and tends to segregate in the melt and which results in lack of homogeneity in the solid product. Moreover, chromium being lighter than copper, it is difficult to keep the chromium submerged for the time required to dissolve it. The chromium tends to rise to the surface of the melt where oxides are formed that contaminate the product.

The chromium may be added to the copper melt in a finely divided form. In practice, it is found that finely divided chromium or a mixture of finely divided chromium and copper when added to the copper melt in the form of a compacted mass is dissolved and does not tend to segregate. Good results have been obtained by

adding the chromium to the copper melt as a cake, pellet, or rod compacted from intermixed copper and chromium powders. The intermixed powders may be compressed to give the resulting mass a predetermined density of about 8.5. In some instances the mass is prepared from the powders by an alternating pressing and sintering treatment. The finely divided chromium powders also may be enclosed in copper tubes of suitable size which may thereafter be swaged to suitably compact the chromium powders. Small amounts of scavenging material, such as suitable forms of calcium, barium, magnesium, phosphorus, or silicon, or slag forming materials, such as B_2O_3, borax, or CaF_2 may be compacted with the finely divided chromium powders. In such manner the required scavenging and hardening agents in predetermined quantities may be added with the chromium to the copper melt.

The alloys described hereinbefore have excellent mechanical properties and high thermal and electrical conductivity when heat-treated, as will be described hereinafter. They may be employed in making castings of complicated design. The copper base alloys containing between .08% and 2.54% of chromium, and preferably between .5% and 1.5% chromium, are particularly useful in making sand castings of complicated shapes.

It is found that when casting copper base alloys where the chromium content is above 1.5%, there is a tendency for the chromium to separate and segregate at the top of the casting, and thus to produce unsound castings. This segregation effect in alloys of high chromium content may be reduced by the use of rapidly cooled molds and by bottom pouring of the casting.

Where the chromium content of the alloy is about .5% good castings can be obtained where slower cooled types of molds are employed. The alloys containing about .5% chromium pour readily and the resulting casting is found to have excellent mechanical properties and conductivity when suitably heat-treated.

In practice the castings made from the alloys composed basically of copper and described hereinbefore are aged by a suitable heat-treatment to develop the mechanical properties and to impart thereto a high conductivity. A method which has been found to be satisfactory for heat-treating the alloys to develop their physical characteristics and conductivity is to heat the casting to a temperature somewhat below the melting point of the alloy, quench, or quickly cool it, and then reheat the casting at some intermediate temperature.

In order to explain the function of the heat-treatment, which is termed a precipitation hardening treatment, and to clarify the meaning of the expression "precipitation hardening," the following explanation is offered: Precipitation hardening is a phenomena which occurs in alloys in which there is a relatively high solubility at elevated temperatures and relatively low solubility at lower temperatures. The solid solution secured at high temperatures on cooling may precipitate in such a fashion as to harden the matrix of the material. In order to secure the desired hardness which is indicative of the strength of the alloy, it is necessary to quench the alloy from an elevated temperature which leaves the solid solution in an unstable condition, and then allow the material to age, during which time a very fine precipitate is formed which contributes to the hardness of the matrix. This ageing is obtained by heating the material at a moderately elevated temperature for a period of time, it being found that as a result of the precipitation of material from solid solution, the matrix becomes more nearly a pure metal and has, consequently, a higher electrical and thermal conductivity.

A preferred precipitation hardening treatment comprises heating the casting to a temperature between 600° C. and 1000° C., quenching, or quickly cooling it, and then reheating it to between 250° C. and 600° C. If the article is not too complicated in shape, an intermediate cold working step may be interposed between the quenching and ageing steps.

Referring to the drawings, there is illustrated some of the results obtained when the alloy composed basically of copper is subjected to the precipitation hardening heat-treatment. In Fig. 1 the curves represent the effect obtained on the hardness by quenching the copper base alloy containing about .45% chromium, and in the form of a sand casting from different temperatures, and ageing the quenched casting at a temperature of 450° C. for periods of time up to 64 hours.

The curve of Fig. 2 is illustrative of the effect of different ageing temperatures for periods of time of about two hours on the copper base alloy containing 2.54% chromium, which has been quenched from a temperature of 950° C. This curve indicates that a preferred ageing temperature of between 400° C. and 550° C. is desirable for this particular alloy when quenched from 950° C.

Referring to Fig. 3, the curves illustrate that the period of time necessary to age the alloy varies and becomes shorter as the ageing temperature is increased. With a copper base alloy containing 2.54% chromium and quenched from a temperature of 950° C., it is found that an ageing treatment at 400° C. requires about 250 hours to develop maximum hardness, whereas by ageing at a temperature of about 450° C., the ageing time is reduced to 16 hours for developing maximum hardness. Upon ageing at 500° C., the time of ageing is further reduced to about three hours for obtaining maximum hardness.

The effect of different chromium contents on the ageing characteristics is illustrated by the curves of Fig. 4. The alloys containing the different chromium contents ranging from .08% to 2.54% were all quenched from a temperature of 950° C. and then aged at a temperature of 450° C. As illustrated, in every case, an increase in the hardness of the treated alloy is obtained. For alloys containing above about .45% chromium, the curves indicate that there is no advantage in ageing the alloys for more than about 16 hours.

The precipitation hardening treatment improves the physical properties and the conductivity of the alloys. For example, the copper base alloy containing about .45% chromium has a conductivity of about 40% as quenched. When aged at a temperature of about 450° C., it is found that the conductivity is increased to 87% as compared to the conductivity of copper. The copper base alloy containing 1.5% chromium and 2.6% zirconium has a Brinell hardness of 71 and a conductivity of 27% as quenched from a temperature of 950° C., and when aged at 450° C. the hardness of the alloy is increased to 152 Brinell, with an accompanying increase in the conductivity to 65%. By decreasing the zirconium content, the conductivity may be further increased to about 80% that of copper. The copper base alloy containing 1% chromium and 2% cadmium has a Brinell hardness of 59 and a conductivity

of 50% when quenched from 950° C., and by ageing the alloy at 450° C., the hardness is increased to 116 Brinell, while the conductivity is increased to 90%.

In general, the precipitation hardening treatment imparts a conductivity of more than 60% of the conductivity of pure copper to the copper base alloys referred to hereinbefore. In most cases the precipitation hardening treatment imparts an average conductivity of over 85% that of copper to the alloys utilized in this invention and which are formed under commercial conditions into articles, as by forging, casting, or cold working to the required shape of the article.

Referring to Fig. 5, the curves thereof illustrate the simultaneous increase in both the mechanical properties and conductivity imparted to the copper base alloy containing .8% chromium as aged after quenching from 950° C. The conductivity indicated is the electrical conductivity, but it is to be noted that the improvement in the electrical conductivity is also a measure of the improvement obtained in thermal conductivity.

The improvement in the ultimate yield point and proportional limit as well as the retention of desirable values of elongation and reduction of area, as obtained in sand castings of the alloy, is illustrated by the curves of Fig. 6, the values for the "as cast" and "as quenched" condition, together with the values for different periods of time of ageing being illustrated. In addition, the impact strength is improved, it being found that a sand casting of the copper base alloy containing .45% chromium has an impact strength of 45 to 50 foot-pounds at temperatures up to 400° C. after having been precipitation hardened by quenching from 950° C. and aged at 450° C.

Where the form of the cast or forged article permits cold working, the article can be subjected to such working after the precipitation hardening treatment. In some cases the hardness of the precipitation hardened alloys is increased from 125 to 135 Brinell by sufficient cold rolling of the articles to effect a 15% reduction in thickness. Cold work in the amount necessary to effect a 60% reduction in thickness can be applied to the fully aged alloy articles without developing cracks. Where desired, and where the form of the articles make it feasible, the step of cold rolling can be applied to the article between the quenching and ageing steps of the precipitation hardening treatment. A hardness of the order of 135 Brinell has been obtained where a 15% reduction in size is applied to the article before the ageing treatment.

Unworked copper base articles which are massive and/or of complicated form can be produced in accordance with this invention having a conductivity of more than 60% and preferably 85 to 93%, together with a hardness of over 110 Brinell, an ultimate strength of 56,000 pounds per square inch, a 25% elongation and high resistance to creep. Some of the articles formed are commutator segments and large castings, such as collector rings for large current generators. Other articles that have been formed are tips for mechanically operated welding electrodes, welding wheels, current collecting nozzles on automatic arc welding heads and cylinder heads for internal combustion engines.

Referring to Figs. 7 and 8 of the drawings, there are illustrated two types of cylinder heads for internal combustion engines formed of the alloys referred to hereinbefore and precipitation hardened. The cylinder heads may be of any predetermined shape or size depending upon the engines with which they are to be employed and may be of the water-cooled type, as illustrated in Fig. 7, or of the air-cooled type, as illustrated in Fig. 8. Where desired, instead of forming the whole head of copper base alloys as illustrated in Fig. 7, only the section of the head forming the dome of the cylinder head may be formed of the copper base alloy and precipitation hardened, the other parts of the head forming the water jacket being made from cast iron or the like.

The alloys composed basically of copper and susceptible to precipitation hardening are particularly suitable for fabrication into cylinder heads, since they can be cast or forged while soft to a predetermined shape after which the formed heads can be subjected to the precipitation hardening heat-treatment described to improve the physical properties and the thermal conductivity of the head. The cylinder heads so formed retain their physical properties even after prolonged exposure to the high temperatures, such as are developed in the firing chamber of the engine during service. Further, a thermal conductivity of at least 60% of that of pure copper is imparted to the alloys by the precipitation hardening treatment which improves the performance of internal combustion engines equipped with such heads. The improved thermal conductivity permits a quick even dissipation of the heat through the walls of the head. In practice, it is found that an engine equipped with the cylinder head of this invention operates at a higher compression ratio without detonation and develops a maximum power and a peak R. P. M. greatly in excess of that which can be developed by the same engine equipped with a cylinder head of aluminum.

We claim as our invention:

1. A cylinder head for internal combustion engines formed of an alloy composed basically of copper which is precipitation hardened imparting thereto the necessary thermal conductivity.

2. A cylinder head for internal combustion engines formed of a precipitation hardened alloy composed basically of copper and containing a relatively small amount of chromium.

3. A cylinder head for internal combustion engines formed of a precipitation hardened alloy composed basically of copper and containing relatively small amounts of chromium and silicon.

4. A cylinder head for internal combustion engines formed of an alloy composed basically of copper which is precipitation hardened imparting thereto a thermal conductivity of at least 60 per cent of the thermal conductivity of pure copper.

5. A cylinder head for internal combustion engines formed of a precipitation hardened alloy composed basically of copper and containing between 0.15 per cent and 2.54 per cent of chromium.

6. A cylinder head for internal combustion engines formed of a precipitation hardened alloy composed basically of copper and containing relatively small amounts of chromium and silver.

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